of October there would be little or no chance of recovering the comet.

The comet's heliocentric equatorial-coordinates at perihelion are—

$$x \ldots -1{\cdot}1148 \qquad y \ldots -0{\cdot}4305 \qquad z \ldots +0{\cdot}0018.$$

If we combine these with the sun's coordinates, X, Y, Z, in the *Nautical Almanac*, we readily obtain an idea as to the chances of finding the comet, according to different assumed dates of arrival at perihelion. The most advantageous conditions are presented when this falls about the middle of April. If we assume April 11, the R.A. is found to be 208°, N.P.D. 54°, and the intensity of light 11·05, which is four times greater than on the date of the comet's discovery by Tuttle in 1858. As it was then extremely faint, its rediscovery may be a matter of difficulty. We have already one "Tuttle's comet," of short period, and it may perhaps occur to astronomers that the third of 1858 will be aptly named *Schulhof's comet*.

CHEMICAL NOTES

Potilitzin has recently (*Ber.*, xvii. 276) made some interesting observations on the hydration and dehydration of cobalt chloride. He shows that, besides the already known hydrate $CoCl_2 . 6H_2O$, there exist two hydrates, $CoCl_2 . 2H_2O$ and $CoCl_2 . H_2O$, the former being rose-red in colour, and the latter dark violet. When the dehydrated salt is heated to about 100°, it parts with water, which is again absorbed on cooling. When an aqueous solution of the ordinary hexhydrated salt is heated, or is mixed with a dehydrating agent, the colour changes from pink to blue or dark violet. Potilitzin shows that this change, which he proves to be due to partial decomposition of the hexhydrated salt, may be brought about without raising temperature by the capillary action of unsized paper or a porous plate of stucco.

Tollens has made experiments on the sugar-like substance obtained by the action of alkalies on an aqueous solution of formaldehyde. He oxidises methylic alcohol by air in presence of platinum foil at 54°–55°, and distils; he then treats the crude distillate with baryta water, and so obtains a yellowish precipitate, which, when freed from barium, yields an amorphous syrup that reduces Fehling's solution, and gives results on analysis approximating to the formula $C_6H_{10}O_5$. This syrup is optically inactive, and does not undergo fermentation; on treatment with sulphuric acid, it gives formic and lactic acids (*Landw. Versuchs-Stat.*, xxix. 355).

Kannonikow (*Ber.*, xvii. p. 157, *abstracts*) attempts to measure the refraction-equivalents of various metals by deducting the refraction-equivalents of salts of these metals with organic acids (determined with aqueous solutions of the salts) from the refraction-equivalents of the acids themselves. So far as his results go, they appear to indicate that the refraction-equivalents vary periodically with variations in the atomic weights of the metals.

MM. Nilson and Petterson have prepared pure beryllium chloride by heating the metal in perfectly dry hydrochloric acid gas, and have determined the density of the vapour of this compound. Beryllium chloride can be volatilised without decomposition in an atmosphere of dry nitrogen or carbon dioxide, provided every trace of air is excluded. The density of the gaseous compound for the temperature-interval 686°–812° agrees with that calculated from the formula $BeCl_2$ (Be = 9·1). The question as to the value to be assigned to the atomic weight of beryllium, which has been so much discussed of late, appears to be now finally settled in favour of the number deduced by applying the periodic law to the study of the properties of this metal and its compounds (*Ber.* xvii. 987).

Continuing the researches of Krämers, Prof. Mendeléeff has shown at a recent meeting of the Russian Chemical Society (*Journal* of the Society, vol. xvi. fasc. 2) that the densities of solutions of salts increase together with the increase of their molecular weights. Thus if we take the series of salts HCl, LiCl, NaCl, KCl, . . . $BaCl_2$, $SnCl_4$, $HgCl_2$, and Fe_2Cl_6, the molecular weights of which are respectively 36·5, 42·5, 58·5, 74·5, . . . 208, 259, 271, and 325, the densities of their solutions in 100 parts of water, at 15° to 20°, are: 1·010, 1·014. 1·023, 1·025, . . . 1·098, 1·106, 1·128 (calculated), and 1·134. The densities increase as the molecular weights increase; but if we take, instead of the molecular weights, the weights of their equivalents, or those of the equivalents of metals, the regularity of increase disappears. Prof. Mendeléeff adds that the above is true, not only with regard to chlorides, but also with regard to the salts of bromine and iodine, and many others. Reserving to himself further to pursue his researches in this way, Prof. Mendeléeff points out the following relation:—If the molecular weight of the dissolved body be M, and the solution be represented by $nM + 100\,H_2O$ (where n represents the number of molecules), the density, D, of the solution may be expressed for many bodies by the following equation:— $\left(\frac{n}{D - D_0}\right)^k = A + Bn$, where D_0 is the density of water, and k is equal to unity, or very near to it. This equation must be considered, however, only as preliminary, ulterior researches promising to give a more general formula. A and B are two constants, which vary with the temperature. Thus, for HCl at 0° (the density of water at 4° being taken = 1), $A = 94{\cdot}5$ and $B = 1{\cdot}725$; at 20°, $A = 102{\cdot}2$, and $B = 1{\cdot}80$; at 40° $A = 106{\cdot}2$, and $B = 1{\cdot}85$; at 60° $A = 105{\cdot}2$, and $B = 2{\cdot}05$; at 80° $A = 100{\cdot}6$, and $B = 2{\cdot}25$; and at 100° $A = 94{\cdot}5$, and $B = 2{\cdot}55$, the coefficient k being in all cases equal to unity.

ON THE NOMENCLATURE, ORIGIN, AND DISTRIBUTION OF DEEP-SEA DEPOSITS[1]

Introduction

The sea is unquestionably the most powerful dynamic agent on the surface of the globe, and its effects are deeply imprinted on the external crust of our planet; but among the sedimentary deposits which are attributed to its action, and among the effects which it has wrought on the surface features of the earth, the attention of geologists has, till within quite recent times, been principally directed to the phenomena which take place in the immediate vicinity of the land. It is incontestable that the action of the sea along coasts and in shallow water has played the largest part in the formation and accumulation of those marine sediments which, so far as we can observe, form the principal strata of the solid crust of the globe; and it has been from an attentive study of the phenomena which take place along the shores of modern seas that we have been able to reconstruct in some degree the conditions under which the marine deposits of ancient times were laid down.

Attention has been paid only in a very limited degree to deposits of the same order, and, for the greater part, of the same origin, which differ from the sands and gravels of the shores and shallow waters only by a lesser size of the grains, and by the fact that they are laid down at a greater distance from the land and in deeper water. And still less attention has been paid to those true deep-sea deposits which are only known through systematic submarine investigations. One might well ask what deposits are now taking place, or have in past ages taken place, at the bottom of the great oceans at points far removed from land, and in regions where the erosive and transporting action of water has little or no influence. Without denying that the action of the tidal waves can, under certain special conditions, exert an erosive and transporting power at great depths in the ocean, especially on submerged peaks and barriers, it is none the less certain that these are exceptional cases, and that the action of waves is almost exclusively confined to the coasts of emerged land. There are in the Pacific immense stretches of thousands of miles where we do not encounter any land, and in the Atlantic we have similar conditions. What takes place in these vast regions where the waves exercise no mechanical action on any solid object? We are about to answer this question by reference to the facts which an examination of deep-sea sediments has furnished.

A study of the sediments recently collected in the deep sea shows that their nature and mode of formation, as well as their geographical and bathymetrical distribution, permit deductions to be made which have a great and increasing importance from a geological point of view. In making known the composition of these deposits and their distribution, the first outlines of a geological map of the bottom of the ocean will be sketched.

This is not the place to give a detailed history of the various contributions to our knowledge of the terrigenous deposits in deep water near land, or of those true deep-sea deposits far removed from land, which may be said to form the special subject of this communication. From the time of the first expeditions undertaken with a view of ascertaining the depth of the ocean, small quantities of mud have been collected by the sounding lead and briefly described. We may recall in this connection the experiments of Ross and the observations of Hooker and Maury. These investigations, made with more or less imperfect appliances, immediately fixed the attention, without however giving sufficient information on which to establish any general conclusions as to the nature of the deposits or their distribution in the depths of the sea.

---

[1] A Paper read before the Royal Society of Edinburgh by John Murray and A. Renard. Communicated by John Murray

When systematic soundings were undertaken with a view of establishing telegraphic communication between Europe and America, the attention of many distinguished men was directed to the importance, in a biological and geological sense, of the specimens of mud brought up from great depths. The observations of Wallich, Huxley, Agassiz, Baily, Pourtalès, Carpenter, Thomson, and many others, while not neglecting mineralogical and chemical composition, deal with this only in a subordinate manner. The small quantities of each specimen at their command, and the limited areas from which they were collected, did not permit the establishment of any general laws as to their composition or geographical and bathymetrical distribution. These early researches, however, directed attention to the geological importance of deep-sea deposits, and prepared the way for the expeditions organised with the special object of a scientific exploration of the great ocean basins.

The expedition of the *Challenger* takes the first rank in these investigations. During that expedition a large amount of material was collected and brought to England for fuller study under the charge of Mr. Murray, who has in several preliminary papers pointed out the composition and varieties of deposits which are now forming over the floor of the great oceans. In order to arrive at results as general as possible, it was resolved to investigate the subject from the biological, mineralogical, and chemical points of view, and M. Renard was associated with Mr. Murray in the work. In addition to the valuable collections and observations made by the *Challenger*, we have had for examination material collected by other British ships, such as the *Porcupine*, *Bulldog*, *Valorous*, *Nassau*, *Swallow*, *Dove;* and, through Prof. Mohn, by the Norwegian North Atlantic Expedition. Again, through the liberality of the United States Coast Survey and Mr. A. Agassiz, the material amassed in the splendid series of soundings taken by the American ships *Tuscarora*, *Blake*, and *Gettysburg*, were placed in our hands. The results at which we have arrived may therefore be said to have been derived from a study of all the important available material.

The work connected with the examination and description of these large collections is not yet completed, but it is sufficiently advanced to permit some general conclusions to be drawn which appear to be of considerable importance. In addition to descriptions and results, we shall briefly state the methods we have adopted in the study. All the details of our research will be given in the Report on the Deep-Sea Deposits in the *Challenger* series, which will be accompanied by charts indicating the distribution, plates showing the principal types of deposits as seen by the microscope, and numerous analyses giving the chemical composition and its relation to the mineralogical composition. The description of each sediment will be accompanied by an enumeration of the organisms dredged with the sample, so as to furnish all the biological and mineralogical information which we possess on deep-sea deposits, and finally, we shall endeavour to establish general conclusions which can only be indicated at present.

Before entering on the subject, we believe it right to point out the difficulties which necessarily accompany such a research as the one now under consideration, difficulties which arise often in part from the small quantity of the substance at our disposal, but also from the very nature of the deposit. Since we have endeavoured to determine, with great exactitude, the composition of the deposit at any given point, we have, whenever possible, taken the sample collected in the sounding-tube. That procured by the trawl or dredge, although usually much larger, is not considered so satisfactory on account of the washing and sorting to which the deposit has been subjected while being hauled through a great depth of water. We have, however, always examined carefully the contents of these instruments, although we do not think the material gives such a just idea of the deposit as the sample collected by the sounding-tube. The material collected by the last-named instrument has been taken as the basis of our investigations, although the small quantity often gives to it an inherent difficulty. It was the small quantity of substance collected by the sounding-tube in early expeditions which prevented the first observers from arriving at any definite results; but when such small samples are supplemented by occasional large hauls from the dredge or trawl, they become much more valuable and indicative of the nature of the deposit as a whole. Not only the scantiness of the material, but the small size of the grains, which in most instances make up deep-sea deposits, render the determinations difficult. In spite of the improvements recently effected in the microscopical examination of minerals, it is impossible to apply all the optical resources of the instrument to the determination of the species of extremely fine, loose, and fractured particles. Again, the examination of these deposits is rendered difficult by the presence of a large quantity of amorphous mineral matter, and of shells, skeletons, and minute particles of organic origin. It is also to be observed that we have not to deal with pure and unaltered mineral fragments, but with particles upon which the chemical action of the sea has wrought great changes, and more or less destroyed their distinctive characters.

What still further complicates these researches is the endeavour to discover the origin of the heterogeneous materials which make up the deposits. These have been subjected to the influence of a great number of agents of some of which our knowledge is to a great extent still in its infancy. We must take into account a large number of agents and processes, such as ocean currents; the distribution of temperature in the water at the surface and at the bottom; the distribution of organisms as dependent on temperature and specific gravity of the water; the influence of aërial currents; the carrying power of rivers; the limit of transport by waves; the eruptions of aërial and submarine volcanoes; the effect of glaciers in transporting mineral particles, and, when melting, influencing the specific gravity of the water, which in turn affects the animal and plant life of the surface. It is necessary to study the chemical reactions which take place in great depths; in short, to call to our aid all the assistance which the physical and biological sciences can furnish. It will thus be understood that the task, like all first attempts in a new field, is one of exceptional difficulty, and demands continued effort to carry it to a successful issue.

In presenting a short *résumé* of our methods, of the nomenclature we have adopted, and of the investigation into the origin of the deposits in the deep sea and deeper parts of the littoral zones, we offer it as a sketch of our research, prepared to modify the arrangements in any way which an intelligent criticism may suggest.

Before proceeding to a description of methods and of the varieties of deposits, with their distribution in modern oceans, we will briefly enumerate the materials which our examination has shown take part in the formation of these deposits, state the origin of these materials, and the agents concerned in their deposition, distribution, and modification.

Materials.—The materials which unite to form the deposits which we have to describe may be divided into two groups, viewed in relation to their origin, viz., mineral and organic.

The mineral particles carried into the ocean have a different form and size, according to the agents which have been concerned in their transport. Generally speaking, their size diminishes with distance from the coast, but here we limit our remarks to the mineralogical character of the particles. We find isolated fragments of rocks and minerals coming from the crystalline and schisto-crystalline series, and from the clastic and sedimentary formations; according to the nature of the nearest coasts they belong to granite, diorite, diabase, porphyry, &c.; crystalline schists, ancient limestones, and the sedimentary rocks of all geological ages, with the minerals which come from their disintegration, such as quartz, monoclinic and triclinic feldspars, hornblende, augite, rhombic pyroxene, olivine, muscovite, biotite, titanic and magnetic iron, tourmaline, garnet, epidote, and other secondary minerals. The trituration and decomposition of these rocks and minerals give rise to materials more or less amorphous and without distinctive characters, but the origin of which is indicated by association with the rocks and minerals just mentioned.

Although the debris of continental land to which we have just referred plays the most important *rôle* in the immediate vicinity of shores, yet our researches show beyond doubt that when we pass out towards the central parts of the great ocean basins, the debris of continental rocks gradually disappears from the deposits, and its place is taken by materials derived from modern volcanic rocks, such as basalts, trachytes, augite-andesites, and vitreous varieties of these lithological families, for instance, pumice, and loose, incoherent, volcanic particles of recent eruptions, with their characteristic minerals. All these mineral substances being usually extremely fine or areolar in structure, are easily attacked by the sea water at the place where they are deposited. This chemical action brings about an alteration of the minerals and vitreous fragments, which soon passes into complete decomposition, and in special circumstances gives rise to the formation of secondary products. In some places the bottom of the sea is covered with deposits due to this chemical action, principal among which is clayey matter, associated with which there are often concretions composed of manganese and iron. In other regions the reactions which result in the formation of argillaceous matter from volcanic products give rise also to the formation of zeolites.

Among other products arising from chemical action, probably combined with the activity of organic matter, may be mentioned the formation of glauconite and phosphatic nodules, with, in some rare and doubtful examples, the deposition of silica. The decomposition of the tissues, shells, and skeletons of organisms adds small quantities of iron, fluorine, and phosphoric acid to the inorganic constituents of the deep-sea deposits.

Finally, we must mention extra-terrestrial substances in the form of cosmic dust.

We now pass to the consideration of the *rôle* played by organisms in the formation of marine deposits. Organisms living at the surface of the ocean, along the coasts, and at the bottom of the sea are continually extracting the lime, magnesia, and silica held in solution in sea water. The shells and skeletons of these, after the death of the animals and plants, accumulate at the bottom and give rise to calcareous and siliceous deposits. The calcareous deposits are made up of the remains of coccospheres, rhabdospheres, pelagic and deep-sea Foraminifera, pelagic and deep-sea Mollusks, Corals, Alcyonarians, Polyzoa, Echinoderms, Annelids, Fish, and other organisms. The siliceous deposits are formed principally of frustules of Diatoms, skeletons of Radiolarians, and spicules of Sponges.

While the minute pelagic and deep-sea organisms above mentioned play by far the most important part in the formation of deep-sea deposits, the influence of Vertebrates is recognisable only in a very slight degree in some special regions by the presence of large numbers of sharks' teeth, and the ear-bones and a few other bones of whales. The otoliths of fish are usually present in the deposits, but, with the exception of two vertebræ and a scapula, no other bones of fish have been detected in the large amount of material we have examined.

Agents.—Having passed in review the various materials which go to the formation of deposits in the deep water immediately surrounding the land and in the truly oceanic areas, attention must now be directed to the agents which are concerned in the transport and distribution of these, and to the sphere of their action. The relations existing between the organic and inorganic elements of deposits to which we have just referred, and the laws which determine their distribution, will be pointed out at the same time.

The fluids which envelop the solid crust of the globe are incessantly at work disintegrating the materials of the land, which, becoming loose and transportable, are carried away, sometimes by the atmosphere, sometimes by water, to lower regions, and are eventually borne to the ocean in the form of solid particles or as matter in solution. The atmosphere when agitated, after having broken up the solid rock, transports the particles from the continents, and in some regions carries them far out to sea, where they form an appreciable portion of the deposit; as, for instance, off the west coast of North Africa and the south-west coast of Australia. Again, in times of volcanic eruptions, the dust and scoria which are shot into the air are carried immense distances by winds and atmospheric currents, and no small portion eventually falls into the sea.

Water is, however, the most powerful agent concerned in the formation and distribution of marine sediments. Running water corrodes the surface of the land, and carries the triturated fragments down into the ocean. The waters of the ocean, in the form of waves and tides, attack the coasts and distribute the debris at a lower level. Independently of the action of waves, there exist along most coasts currents, more or less constant, which have an effect in removing sand, gravel, and pebbles further from their origin. Generally, terrestrial matters appear to be distributed by these means to a distance of one or two hundred miles from the coast. Waves and currents probably have no erosive or transporting power at depths greater than 200 or 300 fathoms, and even at such depths it is necessary that there should be some local and special conditions in order that the agitated water may produce any mechanical effect. However, it is not improbable that, by a peculiar configuration of the bottom and ridges among oceanic islands, the deposit on a ridge may be disturbed by the tidal wave even at 1000 fathoms; and this may be the cause of the hard ground sometimes met with in such positions. By observations off the coast of France it has been shown that fine mud is at times disturbed at a depth of 150 fathoms; but, while admitting that this is the case on exposed coasts, the majority of observations indicate that beyond 100 fathoms it is an oscillation of the water, rather than a movement capable of exerting any geological action, which concerns us in this connection.

Although the great oceanic currents have no direct influence upon the bottom, yet they have a very important indirect effect on deposits, because the organisms which live in the warm equatorial currents form a very large part of the sediment being deposited there, and this in consequence differs greatly from the deposits forming in regions where the surface water is colder. In the same way a high or low specific gravity of the surface water has an important bearing on the animal and vegetable life of the ocean, and this in its turn affects the character of the deposits.

The thermometric observations of the *Challenger* show that a slow movement of cold water must take place in all the greater depths of the ocean from the poles, but particularly from the southern pole, towards the equator. It could be shown from many lines of argument that this extremely slow massive movement of the water can have no direct influence on the distribution of marine sediments.

Glaciers, which eventually become icebergs that are carried far out to sea by currents, transport detrital matter from the land to the ocean, and thus modify in the Arctic and Antarctic regions the deposits taking place in the regions affected by them. The detritus from icebergs in the Atlantic can be traced as far south as latitude 36° off the American coast, and in the southern hemisphere as far north as latitude 40°.

The fact that sea water retains fine matter in suspension for a much shorter time than fresh water should be referred to here as having an important influence in limiting the distribution of fine argillaceous and other materials borne down to the sea by rivers, thus giving a distinctive character to deposits forming near land.

We have pointed out the influence of temperature and salinity upon the distribution of the surface organisms whose skeletons form a large part of some oceanic deposits, and may state also that the bathymetrical distribution of calcareous organisms is influenced by the chemical action of sea water. We will return to these influences presently when describing the distribution of the various kinds of deposits and their reciprocal relations, especially in those regions of the deep sea far removed from the mechanical action of rivers, waves, and superficial currents. The action of life as a geological agent has been indicated under the heading *Materials*.

Methods.—We give here an example showing the order followed in describing the deposits examined:—

Station 338; lat. 21° 15′ S., long. 14° 2′ W.; March 21, 1876; surface temperature 76°·5, bottom temperature 36°·5, depth 1990 fathoms.

GLOBIGERINA OOZE, white with slight rosy tinge when wet; granular, homogeneous, and very slightly coherent when dry; resembles chalk.

i. *Carbonate of Calcium*, 90·38 per cent., consists of pelagic Foraminifera (80 per cent.); coccoliths and rhabdoliths (9 per cent.); Miliolas, Discorbinas, and other Foraminifera, Ostracode valves, fragments of Echini spines, and one or two small fragments of Pteropods (1·38 per cent.).

ii. *Residue*, 9·62 per cent., reddish brown; consists of—

1. *Minerals* [1·62] m. di. 0·45 mm., fragments of feldspar, hornblende, magnetite, magnetic spherules, a few small grains of manganese, and pumice.

2. *Siliceous Organisms* [1·00], Radiolarians, spicules of Sponges, and imperfect casts of Foraminifera.

3. *Fine Washings* [7·00], Argillaceous matter with small mineral particles and fragments of pumice and siliceous organisms.

The description of the deposits has been made upon this plan, which was adopted after many trials and much consideration.

This is not the place to give the reasons which have guided us in adopting this mode of description, or to give in detail the methods that we have systematically employed for all the sediments which we are engaged in describing. These will be fully given in the introduction to our *Challenger* Report. We limit ourselves here to explaining the meanings and arrangement of terms and abbreviations, so that the method may be understood and made available for others.

The description commences by indicating the kind of deposit (red clay, blue mud, Globigerina ooze, &c.), with the macroscopic characters of the deposit, when wet or dry.

We have always endeavoured to give a complete chemical analysis of the deposit, but when it was impossible to do this we have always determined the amount of *Carbonate of Calcium.* This determination was generally made by estimating the carbonic acid. We usually took a gramme of a mean sample of the substance for this purpose, using weak and cold hydrochloric acid. However, as the deposits often contain carbonates of magnesia and iron as well, the results calculated by associating the carbonic acid with the lime are not perfectly exact, but these carbonates of magnesia and iron are almost always in very small proportion, and the process is, we think, sufficiently accurate, for, owing to the sorting of the elements which goes on during collection and carriage, no two samples from the same station give exactly the same percentage. The number which follows the words "*Carbonate of Calcium*" indicates the percentage of $CaCO_3$; we then give the general designations of the principal calcareous organisms in the deposit.

The part insoluble in the hydrochloric acid, after the determination of the carbonic acid, is designated in our descriptions "*Residue.*" The number placed after this word indicates its percentage in the deposit; then follow the colour and principal physical properties. This residue is washed and submitted to decantations, which separate the several constituents according to their density; these form three groups—(1) *Minerals*, (2) *Siliceous Organisms*, (3) *Fine Washings.*

1. *Minerals.*—The number within brackets indicates the percentage of particular minerals and fragments of rocks. This number is the result of an approximate evaluation, of which we will give the basis in our report. As it is important to determine the dimensions of the grains of minerals which constitute the deposit, we give, after the contraction *m. di.*, their mean diameter in millimetres. We give next the form of the grains, if they are rounded or angular, &c.; then the enumeration of the species of minerals and rocks. In this enumeration we have placed the minerals in the order of the importance of the *rôle* which they play in the deposit. The specific determinations have been made with the mineralogical microscope in parallel or convergent polarised light.

2. *Siliceous Organisms.*—The number between brackets indicates the percentage of siliceous organic remains; we obtain it in the same manner as that placed after the word *Minerals.* The siliceous organisms and their fragments are examined with the microscope and determined. We have also placed under this heading the glauconitic casts of the Foraminifera and other calcareous organisms.

3. *Fine Washings.*—We designate by this name the particles which, resting in suspension, pass with the first decantation. They are about 0·05 mm. or less in diameter. We have been unable to arrange this microscopic matter under the category of *Minerals*, for, owing to its minute and fragmentary nature, it is impossible to determine the species. We have always found that the *Fine Washings* increase in quantity as the deposit passes to a clay, and it is from this point of view that the subdivision has its *raison d'être.* We often designate the lightest particles by the name argillaceous matter, but usually there are associated with this very small particles of indeterminable minerals and fragments of siliceous organisms. The number within brackets which follows the words *Fine Washings* is obtained in the same manner as those placed after *Minerals* and *Siliceous Organisms.*

These few words will suffice to render the descriptions intelligible. Greater details will be given, as already stated, in the *Challenger* Report. It may be added that in the majority of cases we have solidified the sediments and formed them into thin slides for microscopic examination, and that at all times the examination by transmitted light has been carried on at the same time as the examination by reflected light. Each description is followed by notes upon the dredging or sounding, upon the animals collected, and a discussion of the analysis whenever a complete analysis has been made, which is always the case with typical samples of the deposits.

Kinds of Deposits.—We now proceed to the description of the various types of deposits into which it is proposed to divide the marine formations that are now taking place in the deeper water of the various oceans and seas. We will speak first of those which are met with in the deeper water of inland seas, and around the coasts of continents and islands, and afterwards of those which are found in the abysmal regions of the great oceans. Those coast formations which are being laid down on the shores, or in very shallow water, and which have been somewhat carefully described previous to the recent deep-sea explorations, are here neglected.

A study of the collections made by the *Challenger* and other expeditions show—

(1) That in the deeper water around continents and islands which are neither of volcanic nor coral origin, the sediments are essentially composed of a mixture of sandy and amorphous matter, with a few remains of surface organisms, to which we give the name of *muds*, and which may be distinguished macroscopically by their colour. We distinguish them by the names, *blue*, *red*, and *green muds.*

(2) Around volcanic islands the deposits are chiefly composed of mineral fragments derived from the decomposition of volcanic rocks. These, according to the size of the grains, are called *volcanic muds or sands.*

(3) Near coral islands and along shores fringed by coral reefs, the deposits are calcareous, derived chiefly from the disintegration of the neighbouring reefs, but they receive large additions from shells and skeletons of pelagic organisms, as well as from animals living at the bottom. These are named, according to circumstances, *coral or coralline muds and sands.*

Let us now see what are the chief characteristics of each of these deposits.

Blue mud is the most extensive deposit now forming around the great continents and continental islands, and in all inclosed or partially inclosed seas. It is characterised by a slaty colour which passes in most cases into a thin layer of a reddish colour at the upper surface. These deposits are coloured blue by organic matter in a state of decomposition, and frequently give off an odour of sulphuretted hydrogen. When dried, a blue mud is grayish in colour, and rarely or never has the plasticity and compactness of a true clay. It is finely granular, and occasionally contains fragments of rocks 2 cm. in diameter; generally, however, the minerals, which are derived from the continents, and are found mixed up with the muddy matter in these deposits, have a diameter of 0·5 mm. and less. Quartz particles, often rounded, play the principal part, next come mica, feldspar, augite, hornblende, and all the mineral species which come from the disintegration of the neighbouring lands, or the lands traversed by rivers which enter the sea near the place where the specimens have been collected. These minerals make up the principal and characteristic portion of blue muds, sometimes forming 80 per cent of the whole deposit. Glauconite, though generally present, is never abundant in blue muds. The remains of calcareous organisms are at times quite absent, but occasionally they form over 50 per cent. The latter is the case when the specimen is taken at a considerable distance from the coast and at a moderate depth. These calcareous fragments consist of bottom-living and pelagic Foraminifera, Mollusks, Polyzoa, Serpulæ, Echinoderms, Alcyonarian-spicules, Corals, &c. The remains of Diatoms and Radiolarians are usually present. Generally speaking, as we approach the shore the pelagic organisms disappear; and on the contrary, as we proceed seawards, the size of the mineral grains diminishes, and the remains of shore and coast organisms give place to pelagic ones, till finally a blue mud passes into a true deep-sea deposit. In those regions of the ocean affected with floating ice, the colour of these deposits becomes gray rather than blue at great distances from land, and is further modified by the presence of a greater or less abundance of glaciated blocks and fragments of quartz.

Green Muds and Sands.—As regards their orgin, composition, and distribution near the shores of continental land, these muds and sands resemble the blue muds. They are largely composed of argillaceous matter and mineral particles of the same size and nature as in the blue muds. Their chief characteristic is the presence of a considerable quantity of glauconitic grains, either isolated or united into concretions. In the latter case the grains are cemented together by a brown argillaceous matter, and include, besides quartz, feldspars, phosphate of lime, and other minerals, more or less altered. The Foraminifera and fragments of Echinoderms and other organisms in these muds are frequently filled with glauconitic substance, and beautiful casts of these organisms remain after treatment with weak acid. At times there are few calcareous organisms in these deposits, and at other times the remains of Diatoms and Radiolarians are abundant. When these muds are dried they become earthy and of a gray-green colour. They frequently give out a sulphuretted hydrogen odour. The green colour appears sometimes to be due to the presence of organic matter, probably of vegetable origin, and to the reduction of peroxide of iron to protoxide under its influence. The *green sands* differ from the muds only in the comparative absence of the argillaceous and other amorphous matter, and by the more important part played by the grains of glauconite, which chiefly give the green colour to these sands.

Red Muds.—In some localities, as for instance off the Brazilian coast of America, the deposits differ from blue muds by the large quantity of ochreous matter brought down by the rivers and deposited along the coast. The ferruginous particles when mixed up with the argillaceous matter give the whole deposit a reddish colour. These deposits, rich in iron in the state of limonite, do not appear to contain any traces of glauconite, and have relatively few remains of siliceous organisms.

Volcanic Muds and Sands.—The muds and sands around volcanic islands are black or gray; when dried they are rarely coherent. The mineral particles are generally fragmentary, and consist of lapilli of the basic and acid series of modern volcanic rocks, which are scoriaceous or compact, vitreous or crystalline, and usually present traces of alteration. The minerals are sometimes isolated, sometimes surrounded by their matrix, and consist principally of plagioclases, sanadin, amphibole, pyroxene, biotite, olivine, and magnetic iron; the size of the particles diminishes with distance from the shore, but the mean diameter is generally 0·5 mm. Glauconite does not appear to be present in these deposits, and quartz is also very rare or absent. The fragments of shells and rocks are frequently covered with a coating of peroxide of manganese. Shells of calcareous organisms are often present in great abundance, and render the deposit of a lighter colour. The remains of Diatoms and Radiolarians are usually present.

Coral Muds.—These muds frequently contain as much as 95 per cent. of carbonate of lime, which consists of fragments of Corals, calcareous Algæ, Foraminifera, Serpulæ, Mollusks, and remains of other lime-secreting organisms. There is a large amount of amorphous calcareous matter, which gives the deposit a sticky and chalky character. The particles may be of all sizes according to the distance from the reefs, the mean diameter being 1 to 2 mm., but occasionally there are large blocks of coral and large calcareous concretions; the particles are white and red. Remains of siliceous organisms seldom make up over 2 or 3 per cent. of a typical coral mud. The *residue* consists usually of a small amount of argillaceous matter, with a few fragments of feldspar and other volcanic minerals; but off barrier and fringing reefs facing continents we may have a great variety of rocks and minerals. Beyond a depth of 1000 fathoms off coral islands the debris of the reefs begins to diminish, and the remains of pelagic organisms to increase; the deposit becomes more argillaceous, of a reddish or rose colour, and gradually passes into a Globigerina ooze or red clay. *Coral Sands* contain much less amorphous matter than coral muds, but in other respects they are similar, the sands being usually found nearer the reefs and in shallower water than the muds, except inside lagoons. In some regions the remains of calcareous algæ predominate, and in these cases the name *coralline mud or sand* is employed to point out the distinction.

Such is a rapid view of the deposits found in the deeper waters of the littoral zones, where the debris from the neighbouring land plays the most important part in the formation of muds and sands.

When, however, we pass beyond a distance of about 200 miles from land, we find that the deposits are characterised by the great abundance of fragmentary volcanic materials which have usually undergone great alteration, and by the enormous abundance of the shells and skeletons of minute pelagic organisms which have fallen to the bottom from the surface waters. These true deep-sea deposits may be divided into those in which the organic elements predominate, and those in which the mineral constituents play the chief part. We shall commence with the former.

(*To be continued.*)

THE TWO MANNERS OF MOTION OF WATER[1]

IT has long been a matter of very general regret with those who are interested in natural philosophy that in spite of the most strenuous efforts of the ablest mathematicians the theory of fluid motion fits very ill with the actual behaviour of fluids, and this for unexplained reasons. The theory itself appears to be very tolerably complete, and affords the means of calculating the results to be expected in almost every case of fluid motion, but while in many cases the theoretical results agree with those actually obtained, in other cases they are altogether different.

If we take a small body, such as a raindrop, moving through the air, the theory gives us the true law of resistance; but if we take a large body, such as a ship moving through the water, the theoretical law of resistance is altogether out; and what is the most unsatisfactory part of the matter is that the theory affords no clue to the reason why it should apply to the one class more than to the other.

When seven years ago I had the honour of lecturing in this room on the then novel subject of vortex motion, I ventured to insist that the reason why such ill success had attended our theoretical efforts was because, owing to the uniform clearness or opacity of water and air, we can see nothing of the internal motion, and while exhibiting the phenomena of vortex rings in water, rendered strikingly apparent by partially colouring the water, but otherwise as strikingly invisible, I ventured to predict that the more general application of this method, which I may call the method of colour-bands, would reveal clues to those mysteries of fluid motion which had baffled philosophy.

To-night I venture to claim what is at all events a partial verification of that prediction. The fact that we can see as far into fluids as into solids naturally raises the question why the same success should not have been obtained in the case of the theory of fluids as in that of solids. The answer is plain enough. As a rule there is no internal motion in solid bodies, and hence our theory, based on the assumption of relative internal rest, applies to all cases. It is not, however, impossible that an at all events seemingly solid body should have internal motion, and a simple experiment will show that if a class of such bodies existed they would apparently have disobeyed the laws of motion.

These two wooden cubes are apparently just alike, each has a string tied to it. Now if a ball is suspended by a string you all know that it hangs vertically below the point of suspension, or swings like a pendulum; you see this one does so, the other you see behaves quite differently, turning up sideways. The effect is very striking so long as you do not know the cause. There is a heavy revolving wheel inside which makes it behave like a top.

Now what I wish you to see is that had such bodies been a work of Nature so that we could not see what was going on—if, for instance, apples were of this nature while pears were what they are, the laws of motion would not have been discovered, or if discovered for pears would not have applied to apples, and so would hardly have been thought satisfactory.

Such is the case with fluids. Here are two vessels of water which appear exactly similar, even more so than the solids, because you can see right through them, and there is nothing unreasonable in supposing that the same laws of motion would apply to both vessels. The application of the method of colour-bands, however, reveals a secret—the water of the one is at rest while that in the other is in a high state of agitation.

I am speaking of the two manners of motion of water—not because there are only two motions possible: looked at by their general appearance the motions of water are infinite in number; but what it is my object to make clear to-night is that all the various phenomena of moving water may be divided into two broadly distinct classes, not according to what with uniform fluids are their apparent motions, but according to what are the internal motions of the fluids which are invisible with clear fluids but which become visible with colour-bands.

The phenomena to be shown will, I hope, have some interest in themselves, but their intrinsic interest is as nothing compared to their philosophical interest. On this, however, I can but slightly touch. I have already pointed out that the problems of fluid motion may be divided into two classes, those in which the theoretical results agree with the experimental and those in which they are altogether different. Now what makes the recognition

---

[1] Lecture at the Royal Institution on Friday, March 28, by Prof. Osborne Reynolds, F.R.S.